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DEPARTMENT OF THE ARMY  
Fort Detrick  
Frederick, Maryland

## PESTICIDE AEROSOLS

### Present State and Prospects of Their Use in the Czechoslovak Socialist Republic

[Following is a translation of an article by Dr. V. Koula of UVURV (expansion unknown) of Prague, in the Czechoslovak-language periodical Agrochemie (Agrochemistry), Vol III, No 4, 1963, Prague, pages 66-68.]

**Introduction:** In the postwar years, new and better forms of pesticide preparations were sought both in Czechoslovakia and abroad which would help reduce the hitherto used large doses to a minimum, increase their biological efficiency and the daily output of machinery to the possible maximum, and entirely eliminate the use of water. Most of these requirements could be fulfilled only by aerosols under certain circumstances, which currently were used only in special cases, i.e., mostly against troublesome and disease-carrying insects.

\* \* \*

In the Czechoslovak agriculture, forestry and food industry, research into the use of individual types of aerosols and equipment for their production started in 1949. In the course of the years, Czechoslovakia developed aerosol generators of the Series SAG, VAG, RAG, ZAG, PAG, Solgen R60 and 300(5:7) producing cold aerosols with the aid of pressure-liquefied gases, high speed of air, and solid particles, high pressure, or a combination of these, hot aerosols with the aid of exothermal chemical reactions, heat, velocity of exhaust gases or of air. Since the working principle and the output indices of some of the above mentioned aerosol generators already are generally known today, and since the generators of the Solgen Series will be specially described elsewhere, we mention only the latest types in the development of the PAG Series, the working principle of which and output indices have not been hitherto publicized.

The PAG-I Aerosol Generator is built as a combined trailer machine which can produce both hot and cold aerosol, with its possible application

from one or several points, or even with the aid of a distribution frame. Its essential elements are the rotating blower driven by an auxiliary explosion engine, the combustion chamber with a jet engine, the vaporizing cone, and two gear pumps for the aerosol solution and for the fuel. The generator nebulizes 40 to 350 liters of solution in an hour, and, with the required dose of hot aerosol, it produces particles of an average mass diameter of 15 microns. With increasing dosage, at otherwise constant temperature and air velocity, the average diameter of the particle mass will also increase, and vice versa. If we put the combustion chamber out of function, and provide the vaporizer cone with an end piece with a grid, with a multi-blade propeller, revolving brushes or disks, with one- or multi-armed half Venturi tubes, or with a distribution arm with six end pieces, the generator produces cold aerosol in which the particle masses have an average diameter of 28 microns.

The PAG-I generator can be used for disinfection of vacant ground spaces, against a great variety of pests of forest cultures, orchards, hop-fields and field crops.

The PAG-II Aerosol Generator is built as an attached machine which works on the principle of a pulsating jet, and produces hot aerosol to be applied from one point. Its essential elements are the cup vent, the combustion chamber and the exhaust pipe. Starting is mechanized and is done with the aid of a small piston compressor. In an hour it nebulizes 20 to 160 liters of aerosol solution, and, with the required dosage, produces particles of 12 micr. average mass diameter. With increasing dosage, at constant temperature, the average diameter of the particle masses increases, and vice versa. The PAG-II generator is especially suitable for the care of forests, orchards, hop-fields and enclosed spaces.

The PAG-III Generator was built as a universal attached machine which can produce cold and hot aerosol as well as an economical water spray, and it can be applied from one or several points, or with a distributing frame. Its essential elements are the rotating blower driven by the outlet shaft of the tractor, and a single or multi-armed end piece provided with half double-Venturi tube, the 4-blade propeller or the distributing frame with six end pieces. At 9,000 revolutions, the rotary blower delivers 1,200 m<sup>3</sup> of air at an exit speed of 56 m/sec. In an hour, it nebulizes or sprays 20 to 500 liters of aerosol solution or water, and with the prescribed dosage of cold aerosol, it produces particle masses of 35 micr. average diameter. With increasing dosage, at constant air amount and constant speed, the average diameter of the particle masses will also increase, and vice versa.

With the production of cold aerosol, the PAG-III generator is suitable for the care of forests, hop-fields, and cultivated fields. Due to the great velocity of air, after the machine has been stopped, the aerosol mist does not become exposed at once to unfavorable air currents. Even when applied from several points, the aerosol solution is conducted to the end pieces only by a single large diameter jet, reducing the possibility of

choking to a minimum, and considerably simplifying its occasional cleaning. The PAG-III generator can also nebulize more viscose aerosol solutions, especially colloidal suspensions, the application of which by other machines causes some difficulty. By insertion and connection of a combustion chamber with the jet engine, the PAG-III generator will also produce hot aerosol. All described types of generators were developed as model machines in the Phytopharmaceutical Laboratory of the Division of Plant Protection of the UVURV in Ruzyna.

#### The Preparation of Aerosol Solutions

and lately also of colloidal suspensions received much attention. To this end the whole series of petroleum fractions with flash points from 55° to 305°C, and the tar fractions from dry distillation of coal with a distillation range from 150° to 400°C have been thoroughly studied. For the preparation of an aerosol solution, packing oil for bearings of an average viscosity of about 30E/200C proved to be the best solvent, and then solvent naphtha and polymethylnaphthalenes as auxiliary solvents.

For the preparation of insecticide aerosol solutions, we have used almost all the chlorine, polycyclic chlorine and phosphorus insecticides and acaricides with contact and systemic action available to us. For the preparation of weed-killing solutions we have used primarily esters, amino and sodium-potassium salts of substituted phenoxyacetic acids. The fungicide colloidal suspensions and solutions contain chiefly anorganic compounds of copper, organic compounds of sulphur, tin and other organic matters.

At the beginning of dealing with the problem itself, the entire toxicological problem circle of the given task was divided into four main phases. In the first phase, all questions were solved which were related to the direct and the residual toxicity of insecticides using cold and hot aerosols, and to the secondary effect of the studied substances upon cultivated plants, game animals, domestic animals, and bees.

#### The Direct and the Residual Toxicity

of the cold and hot insecticides, applied by airplane and on the ground, was expressed in LD 50 and in toxicity indices. These were determined under laboratory and field conditions for more than 36 kinds of insects harmful to agriculture, forestry, food industry, in veterinary and human medicine. Against the great majority of these insects the possibly highest efficiency was obtained; moreover, the amount of active material was strikingly reduced in comparison with the formerly used forms. In all cases, accurate methods were worked out for the control of these pests. (5;6;7;8;9)

#### For the First Time, Phosphorus Insecticides Were Used

which had a systemic effect. They were dissolved in mineral oils, then in non-polar solvents which were applied as cold and hot aerosols against

sucking insects, although in their work on the isomerization of Demeton and Metasystox HENGLEIN and SCHRADER (3) discussed the inhibitory effect of non-polar solvents upon the speed of transformation of the thion form into the more effective thiol form. Both authors indicate further that through their roots and leaves, plants can take up systemic insecticides in sufficient amounts only if these have a certain solubility in water, or if they acquire such properties in the course of their regrouping. It follows from this, therefore, that the systemic insecticides, when applied in the form of oily aerosols, would either not be absorbed by the plants at all, or only to a limited extent. After penetration, oils, as practically non-polar solvents, slow down the speed of the transformation of thion form into thiol form, which would be manifested in a reduced speed of action. The results of our tests showed, however, that absorption of these substances, in the form of oily solutions, in view of their increased ability to penetrate the plant cuticle and of smaller losses by evaporation, is not difficult, and that, as non-polar solvents, oils do not slow down the process of transformation within the plant into a form which is efficient as an insecticide.

During random controls of the produced spectrum of particles by the applicator machinery of the L-60 airplane, it was established that the average diameter of the particle masses was far above 100 microns. The applicator machinery produces a high percentage of particles from 5 to over 100 microns. Both value groups have many disadvantages, and they may cause reduced biological efficiency and damage in the treated plants. Since the average diameter of the particle masses is above 100 microns, i.e., above the limits which we have established for aerosols, we cannot consider this form an aerosol, but only a low-volume spray. In the future it would be desirable, however, to return to the spectrum which the original machinery of the K-65 airplane had produced, and where the average diameter of the particle masses was 85 microns.

#### In the Second Phase

problems were solved which were connected with the direct and fumigant toxicity of the cold and hot weed killer aerosols for weeds, and with a secondary effect upon cultivated plants. The aerosol solutions contained esters, amino and sodium potassium salts of substituted phenoxyacetic acids.

Under laboratory conditions, we studied the direct toxicity of the cold and hot aerosols which contained esters of 2,4-dichloro-phenoxyacetic acid (2,4-D), 2-methyl-4-chlorophenoxyacetic acid (MCPA), and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), their mutual combinations and their combinations with 4,6-dinitro-o-cresol (DNOK) on white mustard (*Sinapis alba* L.) cultivated under standard conditions. The obtained results were expressed in LD 50 and in toxicity indices. (10)

Of the studied substances which were applied as cold aerosols, the ester of 2,4,5-T showed the highest toxicity for white mustard. The esters of MCPA were, on the average, more toxic for white mustard than the esters

of 2,4-D. The opinion that the monohalogen derivatives are less toxic than the dihalogen derivatives could not be confirmed in these tests. In the effectiveness of the individual esters of the studied acids, practically no difference was found. The somewhat lower toxicity of the methyl, possibly also of the ethyl esters could be caused by their bad solubility in oil or by the crystallization of the active substances. Next to the esters of 2,4,5-T, DNOK dissolved in oil and applied as a cold aerosol also showed high toxicity for white mustard. The effect of the butylester of 2-chloro-4-nitro-phenyl-thioxyl-glycolic acid resembles the effect of the 2,4-D butylester. The substitution of sulfoxide and the replacement of the chlorine in the *p*-position by a nitro radical did not reduce its toxicity as is the case with sodium salts. On the contrary, in the case of butylester of 2-chloro-4-nitro-phenoxyacetic acid, the replacement of the Cl in the *p*-position by a nitro radical seemed to be very unfavorable so that in the tests the substance showed no measurable value.

The results of the tests with a combination containing esters of 2,4-D and MCPA in different proportions show that esters of MCPA favorably influence the action of these combinations. The high toxicity of a combination containing esters of 2,4,5-T and MCPA is caused by the presence of the 2,4,5-T ester. Similarly as these esters, DNOK in combinations also substantially increased the toxicity for white mustard.

Hot aerosols containing 2,4-D esters and MCPA, in comparison with cold aerosols, in all cases were more toxic for white mustard, whereas the esters of 2,4,5-T no longer showed such higher toxicity. As in the case of the cold aerosols, there was practically no difference in the efficiency of the individual esters of the studied acids. The increased toxicity of hot aerosols may be caused by their smaller particles which penetrate the plant cuticle faster and better.

#### Determining the Fumigant Toxicity

In order to determine the fumigant toxicity of esters, amino and sodium potassium salts of 2,4-D, MCPA and 2,4,5-T under the most natural conditions possible, we arranged a series of laboratory tests in an enclosed space and directly in a current of air where tomato was used as the test plant. With constant concentration of the active substances and constant temperature, the highest fumigant toxicity in the enclosed space and air stream was shown by the esters of 2,4-D and 2,4,5-T. With the increase of the concentration of the active substances and the temperature, the fumigant toxicity was also increased, but it dropped in proportion to the increasing molecular weight of the esters. The fumigant toxicity of diethyl-, trimethylamino-, sodium and sodium-potassium salts of 2,4-D and MCPA as well as of the packing oil No 107 is completely negligible. The results of the laboratory tests for fumigant toxicity were verified under field conditions on those cultivated plants which would be threatened the most in the practical application of weed-killers. The results of these tests indicated that the application of a 10% butylester of 2,4-D and MCPA in the form of cold

aerosols did no damage anywhere to the experimental plants as a result of fumigation. The fact that even with an application of an aerosol, i.e., a form which because of its physical properties could even further aid fumigation, no damage developed, is an interesting fact, since the daily average temperatures during application were relatively high. Packing oil with a high boiling point probably reduced the fumigation of these substances in an open space to an extent that it was no longer dangerous for the currently cultivated field crops.

#### Interesting Results of the Tests

Next to the direct and fumigant toxicity we determined the effect of the studied substances upon transpiration, upon the volume of reducing sugars and saccharase, on the volume of catalase, of peroxidase, polyphenoloxidase, on the volume of the biogenic and trace elements of the cultivated plants. In these experiments, too, very interesting results were obtained.

Under field conditions, the direct toxicity of the butylester, amino, sodium, sodium-potassium salts of 2,4-D, MCPA and 2,4,5-T and of their mutual combinations was established and expressed by loss of chlorophyl, by percentage of dewatering, by the dewatering index, and by the extent of damage for 45 types of weed. The butylester of 2,4-D and MCPA applied by airplane in the form of a cold aerosol in the amount of 550 g of active substance, the amino salt in the amount of 1000 g of active substance, and the sodium-potassium salt applied by airplane as a low-volume spray and on the ground as a cold aerosol in the amount of 1500 g of active substance in doses of  $5\frac{1}{2}$  to 6 liters per hectare showed the highest possible effectiveness in the experiments against all weeds. In view of the high toxicity of both esters, i.e., both to weeds and to cultivated plants, and in view of the unfortunate technical condition of the applicator machinery on the L-60 airplanes, it was decided that the application of these substances and forms will be suspended, and, following improvement of the machinery, we will concentrate on aerial application of low-volume aqueous sprays containing a 25% sodium-potassium salt of MCPA in doses of 6 liters per hectare. The ground application of the above-mentioned substances, including the polyamino salts of 2,4-D will continue to be carried out in the form of cold aerosols, likewise in doses of 6 l/hectare.

The field trials made with an application of hot aerosols containing butylesters of 2,4,5-T and applied with the RAG-II manual generator showed that in this manner also, the focus of weeds is very well destroyed, especially in garbage dumps.

#### In the Third Phase

all problems are dealt with which are related to the fungistatic, resp. fungicidal action of aerosol colloidal suspensions containing copper oxide, TMTD, dimethyl-dithiocarbamate of Zn, Zn ethylene-bis-dithiocarbamate, triphenyl-stannoacetate and organic compounds of the captan type. In

approaching this problem extraordinary attention was devoted to the questions that are closer related to the release of anorganic and organic compounds from the oily phase. In a whole series of laboratory, physico-chemical and biological experiments it has been definitely shown that copper and other organic substances can be released from this phase, and can act in a fungistatic manner. In solving this series of problems we endeavored, first of all, to use these forms to control cercosporosis (*Cercospora beticola* Sacc.), and the potato mould (*Phytophthora infestans* [Mont.] de Bary). Results of experiments over the years have shown after statistical elaboration that in comparison with a substance of known effect the colloidal suspension containing 25% of copper oxide and applied in the form of a cold aerosol is especially capable of substantially reducing the incidence of diseases. It seems that even triphenyl-stanno-acetate will find considerable use against both diseases mentioned. In future years, the effect of fungicide aerosols will also be studied on the remaining diseases of cultivated plants.

In the fourth phase, questions will be dealt with which are related to the use of cold aerosols for soil disinfestation and disinfection, in combination with fluid and pressure-liquefied fertilizers, and later also questions related to the use of individual hot and cold aerosols for such purposes.

#### Pesticides and Artificial Fertilizers

At the present time, we either use individual pesticide substances for the disinfestation of soil or they are used in combination with artificial fertilizers. These combinations, the use of which today has become more extended and which show considerable advantages, are prepared either by simple mixture of pesticides with artificial fertilizers, or by their impregnation with pesticide solutions. In the form of dusts, granules, solutions, emulsions and suspensions they are introduced into the ground by the most diverse methods, (1:2:4) Combinations prepared in this manner as well as the existing method of their insertion have many shortcomings which are especially due to the large consumption of active substances, and to their complicated preparations. Moreover, the pesticide substances penetrate at shallow depths and their distribution in the soil is uneven. We believe that -- by improving these combinations in an aerosol form, by use of suitable pesticide substances which tolerate the reaction medium, and of liquid pressure-liquefied artificial fertilizers, such as ammonia which serves also as an aerosol propellant -- the existing shortcomings can be eliminated. With the use of such a combination in the form of cold aerosols, it may be assumed that there will be a more complete penetrating flow into deeper layers of the ground, and as a result, a physical bondage of the pesticides to the colloidal particles of the ground and their more even distribution in the layers. Both these momentums can favorably influence the production of more perfect disinfestation and disinfection zones, and can thus increase the biological efficiency of pesticides. The application of pesticides in combination with fluid pressure-liquefied fertilizers in the form of cold aerosols can be carried out by currently used ammonia machinery.

With the successful solution of this latest phase, the work on the given task is still far from being completed. Further ways will be sought for the continued utilization of aerosols in the control of the harmful agents of cultivated plants.

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Read by Eng. Obenberger.

FIGURE CAPTION APPENDIX

1. PAG-I aerosol generator combi. Orig. Dr. Koula, photo M. Novak, UVURV, Ruzyna.
2. PAG-II aerosol generator with production of hot aerosol for the care of orchards. Orig. Dr. Koula, photo M. Novak, UVURV, Ruzyna.
3. PAG-III aerosol generator combi with production of cold aerosol for the care of forests. Orig. Dr. Koula, photo M. Novak, UVURV.

FIGURES NOT REPRODUCABLE